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CERL'S MODIFIED TYPE 12 IMPACT TOOL

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Canadian Explosives Research Laboratory

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by

E. Contestabile*, E.T. Pike** and T.R. Craig**

ABSTRACT

A drop-weight impact tool was designed for the purpose of testing small samples of explosives and pyrotechnic substances. Denoted as the CERL (Canadian Explosives Research Laboratory) Modified Type 12 Impact Tool, it has proved to be a reliable and flexible experimental apparatus for determining the relative sensitivity of explosives to mechanical impact.

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MOUTON DE CHOC MODIFIÉ DE TYPE 12 DU LCRE

par

E. Contestabile*, E.T. Pike** et T.R. Craig**

RÉSUMÉ

Un mouton de choc a été conçu dans le but d'effectuer des essais avec de petits échantillons d'explosifs et de substances pyrotechniques. On a démontré que le mouton de choc Modifié de Type 12 du LCRE (Laboratoire canadien de recherche sur les explosifs) pouvait être un appareil d'essai efficace et flexible pour déterminer la sensibilité relative des explosifs aux chocs mécaniques.

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INTRODUCTION

The Type 12 drop weight impact tool used at the Canadian Explosives Research Laboratory (CERL) was modified to improve its efficiency and reproducibility. The impacting surface dimensions were retained, however, the following major changes were incorporated. The equipment was designed to,

1. Provide more space in the sample area
2. Provide accurate alignment of the impacting surfaces
3. Provide variable drop and intermediate weights
4. Measure the impulse generated by the drop weight

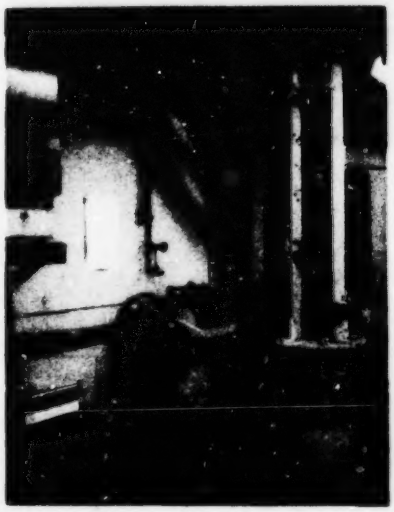
THE NEW TOOL

CERL's original Type 12 impact tool is shown in Fig. 1. The anvil, fastened to the base via a clamping arrangement, is aligned with the small intermediate weight. This assembly was installed in a drop weight apparatus in an area where the working height was 15 cm. This height was increased to 30 cm to accommodate the new tool.

Fig. 1 - Original Type 12 Impact Tool

Figure 2 shows the drop weight apparatus as modified. The electromagnet used to lift the drop weight and the drop weight itself are both visible.

Figure 3 shows the new tool installed in the drop weight apparatus. This has a massive base on which is mounted a thick washer and the anvil. The intermediate weight is permanently aligned to the anvil by a guide, and can be held in the uppermost position by a pin that latches to the guide. (See Fig. 4). This facilitates the placing of the test sample in the tool. Figure 5 shows a cross-sectional view of this new tool.



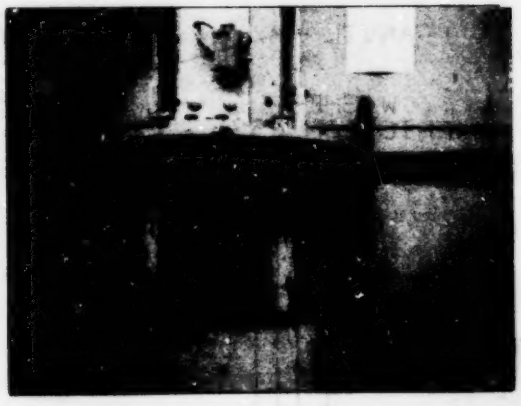


Fig. 3 - Modified tool in drop weight apparatus

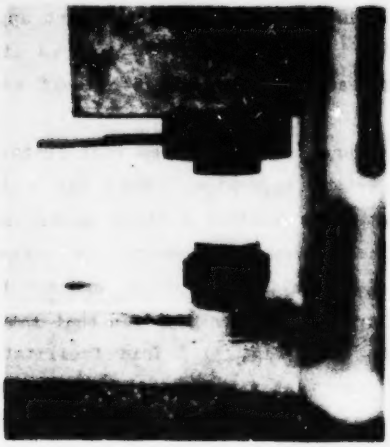
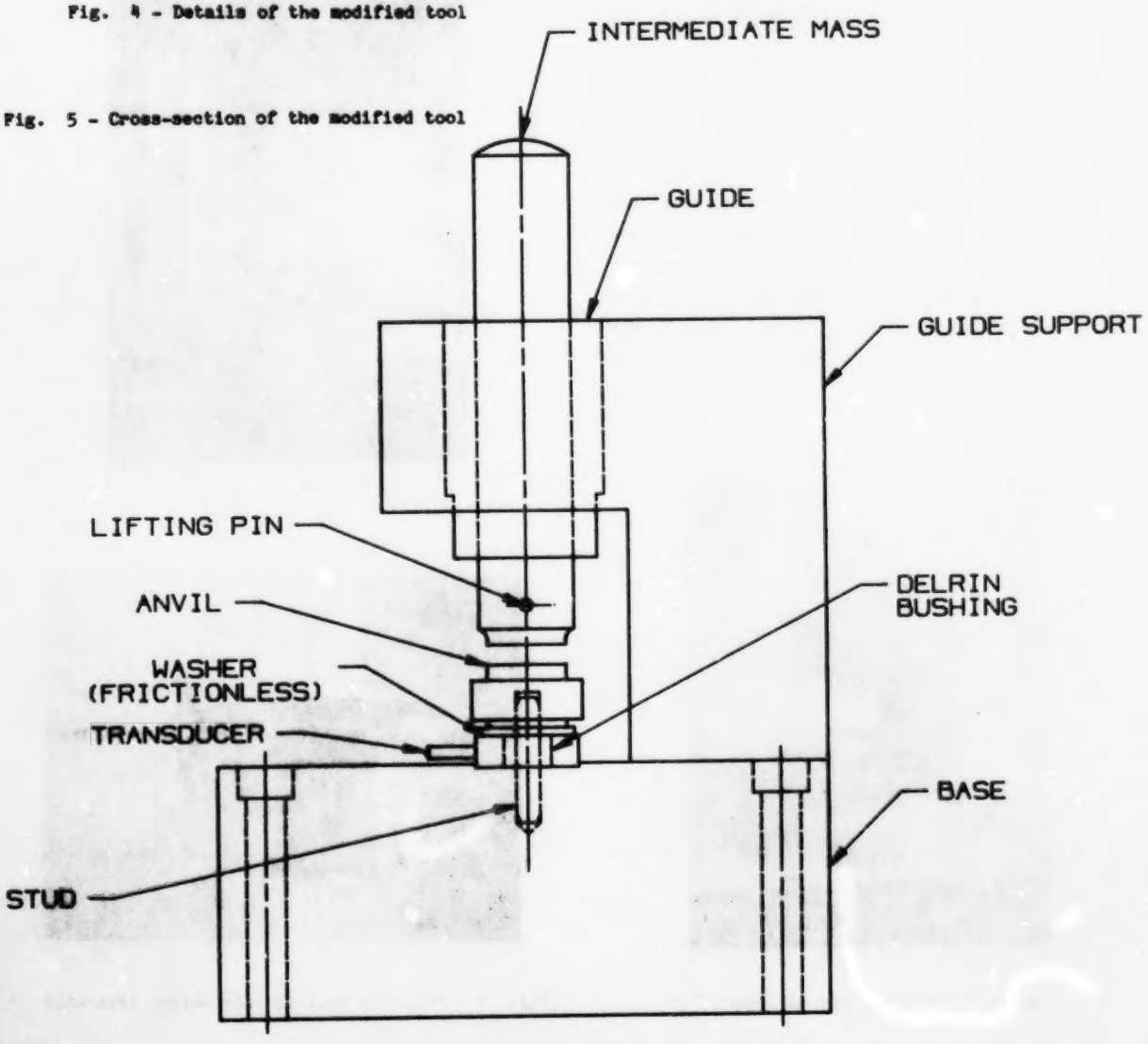


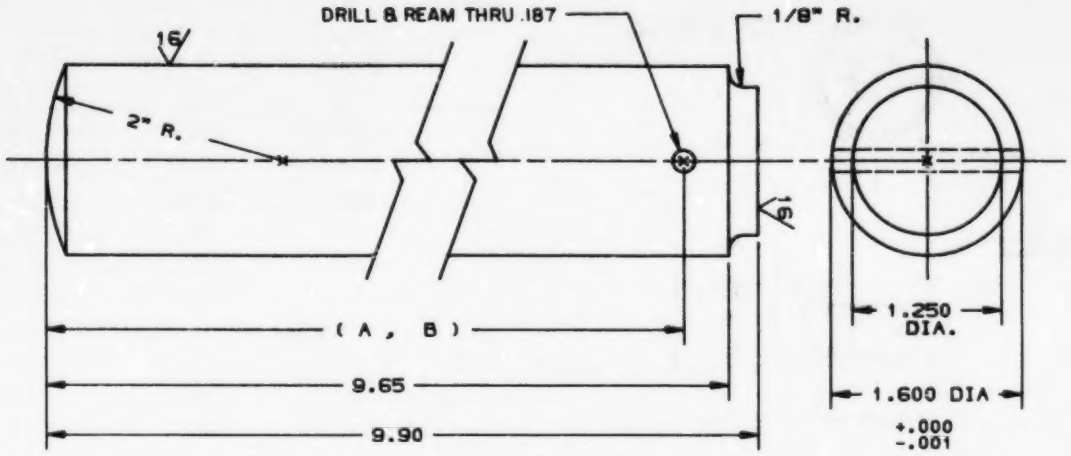
Fig. 4 - Details of the modified tool

The new drop weight impact tool can accommodate different intermediate weights. Those found to be most useful are 2.5 Kg, 2.0 Kg and the 1.5 Kg. All have a 3.2 cm diameter face hardened to 50-53 Rockwell-C. The face of the anvil has the same diameter and hardness. Figure 6 shows the dimensions of the different intermediate weights, and Fig. 7 shows the details of the anvil.

To record the pressure profile generated by the action of the drop-weight, a pressure transducer replaces the thick washer sandwiched

Fig. 5 - Cross-section of the modified tool





DIMENSION (A) IS 9.375 FOR THE 2.5 KG MASS.
DIMENSION (B) IS 7.435 FOR THE 2.0 KG MASS.

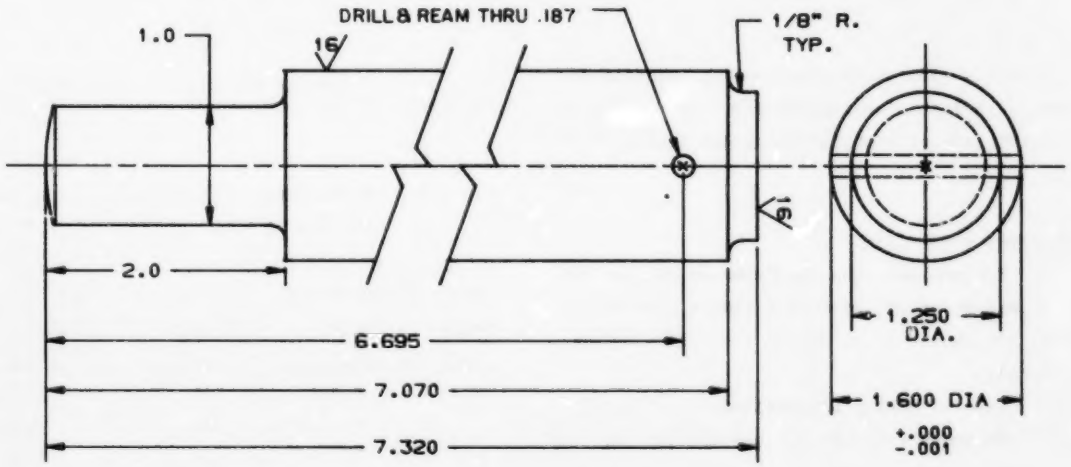
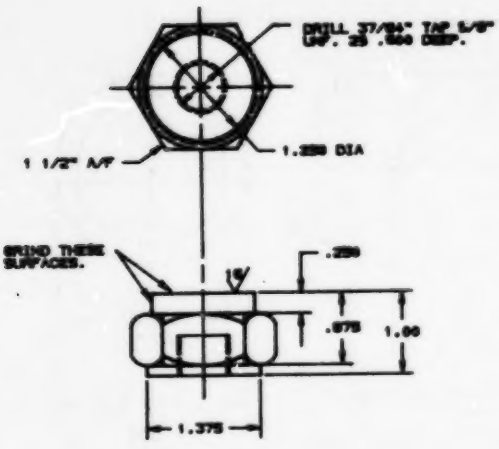


Fig. 6 - The different intermediate weights

between the anvil and the base. The signal from the transducer is displayed on a digital oscilloscope from which a hard copy can be obtained via a plotter.

From previous studies (1), it has been established that as the ratio, R=m2/m1, the mass of the intermediate weight, m2, to the mass of the drop weight, m1, approaches the value of one, the kinetic energy transfer efficiency is maximized. Therefore all the intermediate weights have matching drop weights.

Using the matched drop and intermediate weights, a measure of the rigidity of the apparatus was obtained by determining e, the coefficient of restitution. This was done by releasing the drop weight from a height, h1, and measuring the rebound height, h2. Then, from the relationship, $e=(h2/h1)^{0.5}$, the average values of the coefficient of restitution for the drop heights of 50 cm, 100 cm and 150 cm were determined and are listed in Table 1. Similar results for the previously used Type 12 Tool are shown in Table 2.



MATERIAL: EPS-245 HARDENED 58-63 ROCKWELL "C"

Fig. 7 - Details of the anvil

For perfectly elastic collisions e=1, whereas for perfectly inelastic collisions e=0. From Table 1, the coefficient of restitution ranges from 0.70 to 0.80.

Performance Evaluation

To evaluate the performance of the new tool it was necessary to test a sample over a long period. In choosing the sample the following were considered.

1. Ease of sample preparation
2. Dependence of sample preparation on the operator
3. Availability of sample
4. Chemical and physical stability of sample over time

With the above considerations, the sample chosen for this operation was the DuPont explosive, Detasheet C (2); an explosive that is easily available and is primarily used by the military. Detasheet C is green in colour and is composed of 63% PETN and 8% nitrocellulose and plasticiser. It has the consistency of soft rubber and is available in different shapes such as sheet, cord or ribbon. According to the manufacturer, it has an infinite storage life at room temperature, a density of 1.48 g/cc, and a detonation velocity of 700 m/s. Compared to other explosives it is fairly insensitive to friction and impact.

The samples used in this test series were denoted C1, if cut from the 1.07 mm thick Detasheet and C2, if cut from the 2.11 mm thick Detasheet. Both samples had a 3.86 mm diameter and corresponding mass of 18.5 mg and 36.4 mg. To avoid operator-dependent errors in sample preparation, a metal punch was designed to cut the explosive sheet to the test sizes determined above. All samples were stored in glass jars throughout the test period.

Table 1 - Coefficient of restitution for matched weights at different drop heights (Modified Type 12 Tool)

Matched Weights (Kg)	Drop Height (cm)	Coefficient of Restitution (e)
1.5	50	0.72
	100	0.76
	150	0.76
Average for 1.5 Kg is e=0.75		
2.0	50	0.70
	100	0.76
	150	0.77
Average for 2.0 Kg is e=0.74		
2.5	50	0.80
	100	0.83
	150	0.83
Average for 2.5 Kg is e=0.82		

Table 2 - Coefficient of restitution for old type 12 tool

Drop Weight (Kg)	Intermediate Weight (Kg)	Drop Height (cm)	Coefficient of Restitution (e)
2.5	0.485	50	0.79
		100	0.81
		150	0.81

Table 3 - Drop heights, for 50% fires of detasheet C

Date	Drop height (cm)				
	With sandpaper			No sandpaper	
	C2 cut Dec. 13/76	C2 cut as required	C1 cut as required	C2 cut as required	C1 cut as required
Dec. 13/76	38.1				
Jan. 10/77	38.1				
Feb. 7	39.3				
Mar. 7	39.5				
Apr. 4	43.2	38.5			
May 2	39.4	36.9			
May 30	41.0	39.4			
June 27	39.4	40.2			
July 25	38.5	38.5	38.5		
Aug. 22	38.5	40.2	37.7		
Oct. 17	34.3	33.6	33.1		
Nov. 14	32.5	33.9	32.5		
Dec. 12	32.5	33.7	31.0		
May 2/78		44.2	32.5	200.4	37.8
May 28		38.8	31.9	202.4	36.8
July 24		39.5	27.7	204.1	37.7
Aug. 21		39.7	30.7	207.7	37.5
Sept.18		31.0	17.9	76.5	27.2
Nov. 13		30.9	21.8	61.7	37.5
Dec. 11		31.8	23.2	52.2	41.7

The tests performed generated two sets of data for each sample. The test configurations were as follows.

1. The sample was placed on the bare anvil, the intermediate weight was lowered on it and the drop weight released.
2. The sample was placed on a piece of sandpaper on the anvil, the intermediate weight lowered on it and the drop weight released.

A further distinction was made between old and new samples and test results on samples prepared at the beginning of the test and those prepared at the time of testing. Those samples denoted as "old samples" refer to Detasheet C explosive that had been at the laboratory for at least five years whereas those denoted as "new samples" refer to Detasheet C explosive that had recently been acquired.

In this test series the drop and intermediate weights used varied. Since the matched 2.5 Kg drop and intermediate weights were earlier found to be most useful with the commercial explosives tested, it was the most used combination. However other combinations of weights were also employed. The notation used for the weights involved is illustrated in the following example. For the matched 2.5 Kg intermediate weights used to test a sample placed on a bare anvil the notation is M2525. If the sample is tested on sand paper with, for example, a 2.0 Kg drop weight and a 1.5 Kg intermediate weight, then the notation would be M2015sp.

Most of the tests performed over a two year period at one month interval took place at

room temperature (18°C-22°C). Since little control could be exercised over this environment, there were temperature fluctuations and these are duly noted in the report. The greatest fluctuations occurred between September and December when the cooling system was being turned down while the heating system was coming on. Temperatures during these periods were often in the 25°C to 32°C range, being higher in 1978 than in 1977.

Tests, using the M2520sp weight configuration began on C2 samples initially prepared on December 1976 and continued to April 1977. At this date all the tests to follow were performed with the M2525sp weight configuration. A second run was initiated using samples of C2 that were cut as required. Testing continued to July 1977 when a third run was begun using samples of C1 that were cut as required. Testing of the samples cut on December 1976 ended on December 1977.

After a period of modifications to the building that housed the drop weight impact equipment, testing resumed on May 1978. Test runs two and three continued and two more runs were introduced. Both runs used samples that were cut as required. Run four and five were to test C2 and C1 respectively, on the bare metal anvil. That is, the test configuration used was M2525.

A compilation of the results is given in Table 3. The values are the drop heights at which 50% fires occurred and were determined using a standard up-and-down method (3).

Of the five tests on the C2 samples initially prepared on December 1976 and tested with M2520sp, the first four gave reproducible results. The fifth test, however, resulted in a much higher drop height. This shift to a less sensitive value is attributed to a very low ambient temperature of 8°C on that particular day.

The next eight tests of this same run were performed with the M2525sp configuration. Except for the last three, where the test temperature was about 28°C, the results are fairly constant, ranging from 38.5 cm to 41.0 cm and having an average of 39.4 cm.

The second run on the cut as required C2 sample showed similar behaviour to the first run. Eliminating the data obtained from September to December of 1977 and 1978 when the temperature was above normal, the range of drop heights is from 36.9 cm to 44.2 cm with an average of 39.7 cm.

The third run tested the sample C1. The temperature effect on it did not seem to be as pronounced as on the thicker sample C2, except for the data obtained from September to December 1978 when the temperature was just above 30°C. Eliminating this data, the drop heights range from 27.7 cm to 42.4 cm and the average is 33.3 cm.

Runs four and five were begun late in the program so that little data is available. Both runs were done with the M2525 configuration, that is, with the sample placed directly on the steel anvil. Again the high temperature effect is more noticeable on the C2 sample than on the C1. The only conclusion that can be made with this minimal data is that C1 is much more sensitive than C2 when tested on bare metal. Also, with a range from 27.2 cm to 41.7 cm and an average of 36.6 cm, C1 tested on steel is less sensitive than C1 tested on sandpaper. This is also true for C2, whether the samples were previously prepared or cut as required. There seems to be no detrimental effect in preparing samples ahead of time. Any changes, if any, that may occur on the cut face of the sample is certainly not resolved in this test.

Due to tool and procedural development, and lack of temperature control not all the data qualified for determining the average values. The average drop heights and range for the 50% fires quoted above are listed in Table 4.

Comparison of Test Results of the New Tool to the Old

To best compare results obtained on the old and the new impact tools it was required to test well known explosives at the same temperature, and by different operators. The samples of explosives chosen were those most often referred to in the literature as references for standardizing or comparing mechanical sensitivity tests. These samples are listed in Table 5. All the powdered samples were placed on the piece of sandpaper using a right cylindrical scoop. This

Table 4 - Average drop heights and range for 50% fires for the explosive samples C1 and C2

Drop height (cm)				
With sandpaper			No sandpaper	
C2 cut Dec. 13/76	C2 cut as required	C1 cut as required	C2 cut as required	C1 cut as required
39.4 (38.5-41.0)	39.7 (36.9-44.2)	33.3 (27.7-42.4)	204.9 (200.4-207.7)	36.6 (27.2-41.7)

scoop contains about 35 mg of sample and reduces the operator error in estimating sample size. The Detasheet samples were prepared as described earlier. Testing on the new tool was performed using the weight configuration M2525sp.

Table 5 - Explosive samples used for comparing impact results on the old and the new impact tools

Explosive samples	Description
TNT	Through 80, on 100 mesh
RDX	United Nations round robin sample
PETN	Superfine
Tetryl	NATO round robin sample
Detasheet C1	1.07 mm thick, 3.86 mm diameter
Detasheet C1.5	1.60 mm thick, 3.86 mm diameter

The operators basically interpreted the results similarily. If the impact caused a report, smoke, flame, or smell witnessed, then it was considered a fire. However, if none of the above were witnessed, then the condition of the sample was evaluated. Operators two and three considered the sample to have fired if there was any sign of reaction whereas the other two required that 50% of the sample be consumed to consider it a fire. This led to some discrepancy, especially for the TNT sample tested in the old tool. At times the report was not audible due to the noise from the weight falling from higher drop heights. The results obtained by four operators are listed in Table 6 and plotted in Fig. 8 and Fig. 9. The table lists, H50, the 50% fire level and s, the estimate of the standard deviation in log form. All the tests were performed in the temperature range from 19.0°C to 21.5°C.

The relative order of the H50 for the samples was maintained in all test series except for two. Operator number two reversed the order of the Detasheet samples by a fraction of a centimeter or about 1% of the H50 value. Operator

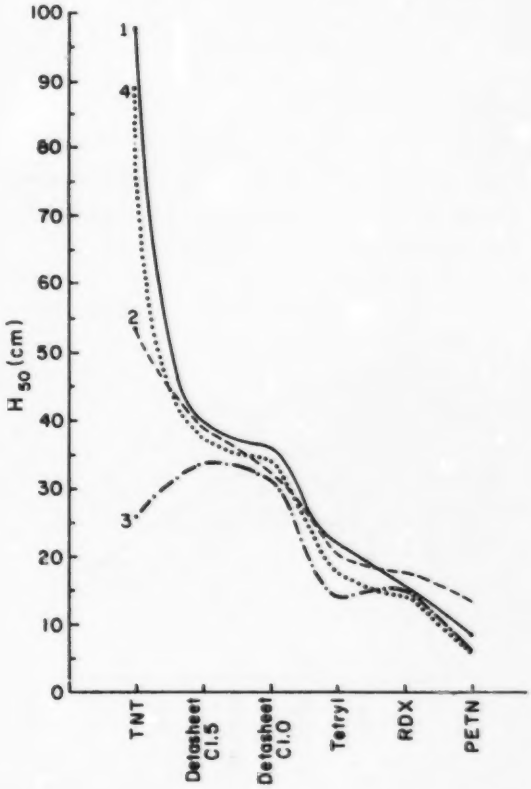


Fig. 8 - Drop weight impact results for the old tool

Table 6 - Drop heights obtained in the old and the modified Type 12 impact tool by four operators for 50% fire of six explosive samples

Explosive Sample	Operators 1		2		3		4	
	H50 (cm)	s	H50 (cm)	s	H50 (cm)	s	H50 (cm)	s
Type 12 Tool								
TNT	97.9	0.08	53.5	0.42	26.2	0.11	89.8	0.20
Detasheet C1.5	39.6	----	38.8	----	33.6	0.08	37.4	----
Detasheet C1.0	35.9	----	32.5	0.08	31.3	0.08	34.3	----
Tetryl	21.8	0.11	20.1	0.14	13.8	0.11	17.7	0.06
RDX	15.8	----	17.6	0.10	15.1	0.15	14.0	----
PETN	8.6	----	13.3	0.15	5.4	0.10	5.8	0.21
CERL's Modified Type 12 Tool								
TNT	29.4	0.22	31.3	0.49	22.2	0.54	19.5	0.07
Detasheet C1.5	33.5	----	27.6	0.06	30.2	0.07	25.0	0.13
Detasheet C1.0	29.9	----	27.9	0.06	23.1	0.07	23.8	0.10
Tetryl	24.0	----	19.4	0.13	13.3	0.14	16.2	0.14
RDX	15.7	----	16.8	0.15	12.4	----	12.0	0.12
PETN	6.4	----	12.5	0.17	6.8	0.34	6.2	0.19

number three, using the old tool, reversed the order of RDX and Tetryl. This operator also obtained very close values for the same samples on the modified tool.

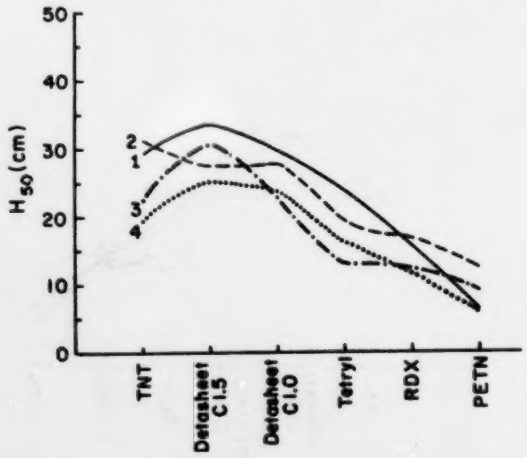


Fig. 9 - Drop weight impact results for the modified tool

As expected, due to the different criteria used to establish a fire over a no-fire, the H50s determined by operators three and four were consistently lower than those obtained by operators one and two. Assuming that the samples behave similarly under impact, it was also expected that the range of H50 values would differentiate the powdered samples from those in plasticized form. Had this occurred, it would have indicated that the method of sample preparation was inappropriate and placement of the sample on the tool was operator-dependent. However, since the only range of H50s that is extremely large is that for TNT, it can be concluded that the method of sample preparation and its placement onto the tool is satisfactory. The range of the H50 values for Tetryl is also slightly larger than that for Detasheet. This, however, is typical of this explosive. A further complication with the Tetryl sample arises from it being in prilled form. This causes problems with sample placement and sample configuration in the tool, that may lead to a wide range of results.

The estimate of the standard deviation, s, tends to reflect the homogeneity or heterogeneity (ie, of slurry explosives) of the sample and to a lesser extent, the sample preparation, the sample's behaviour under impact, the operator's evaluation, and the lumped equipment variables (ie, reproducibility of mechanical behaviour). The above parameters assume constant environmental conditions.

The most striking difference in the results from the two impact tools is that of TNT. The modified tool drastically reduced the range for its H50. This indicates a more efficient energy transfer to the sample. As mentioned earlier, the test configuration M2525sp is presently used on commercial explosives. However it is evident that to better differentiate between the samples tested for this study, the weight configuration M2020sp or possibly M1515sp would be more suitable. This would eliminate the problem encountered in differentiating between fires and no fires as the actual test levels become progressively smaller.

The results also indicate that the efficiency of energy transfer could determine the order in the relative sensitivity. Besides the operator dependent reversals already mentioned, a trend for the modified tool to show TNT as more sensitive than Detasheet is obvious. Since we are dealing with two physically different explosives it is difficult to pinpoint the reason for this occurrence. However, the modified tool does subject the test sample to a different pressure profile for a given drop height. The ensuing response of the sample to this stimulus could cause the explosive to evolve different indicators. It has been observed that explosives do not give the same indicators for evaluating an event caused by mechanical impact. The loudness, the smoke, or the light generated, and the amount of sample consumed varied with the explosive. However, the data implies that it may also be a function of the stimulus.

Capturing the Pressure Profile Generated by the Drop Weight

CERL's goal, in this field, is to eventually state a sample's impact sensitivity in terms of energy transferred to the sample, or rate of energy transfer, or impulse rather than simply the height from which the drop weight is released. As already mentioned, the tool was modified to accept a pressure transducer. Using this force ring, the specifications of which are listed in Table 7, a series of pressure profiles were recorded.

Table 7 - Specifications of pressure transducer

Range Compression	lb	60000
Maximum Force	lb	70000
Resolution	lb	2.0
Resonant Frequency	k Hz	20
Stiffness	lb/μin	62
Bolt Dia. Accepted	in	3/4
	mm	20
Size ID (Hole Dia)	in	0.83
OD	in	1.58
Height	in	0.51
Sensing Surface	in (dia)	1.38
Weight	oz	3.0
MODEL NO. (Voltage Mode) (with built-in amplifier)		205A
Sensitivity	mV/lb	0.1
Connector		Con Hex

Figure 10 and Fig. 11 show pressure profiles for drop heights for 25 cm increments, from 25 cm to 200 cm. Figure 10 was obtained with the intermediate weight interacting with the bare steel anvil, whereas, the configuration for capturing the pressure profiles shown in Fig. 11, was with sandpaper on the anvil. The profiles seem to be similar in duration and amplitude. However, the pressure pulses resulting from the use of sandpaper have a slight distortion to the left of the seemingly sharper peak.

The following three figures illustrate typical pressure profiles obtained by impacting explosive samples. Figure 12 shows two curves for Detasheet C.1. The profile on the left represents a no-fire while that on the right is for a fire. They are rather clean pulses reflecting the plastic nature of the explosive.

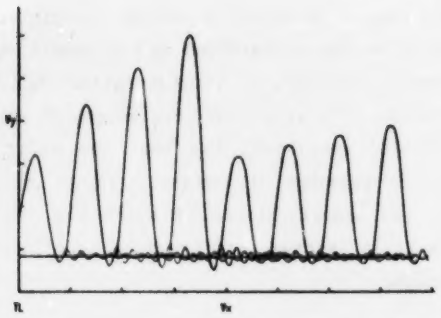


Fig. 10 - Pressure profiles obtained by dropping weight from 25 cm to 200 cm at 25 cm increments, with the intermediate weight on the bare anvil. The horizontal scale is 0.25 ms/div while the vertical scale is 1 v/div for the first four curves and 2.5 v/div for the next four

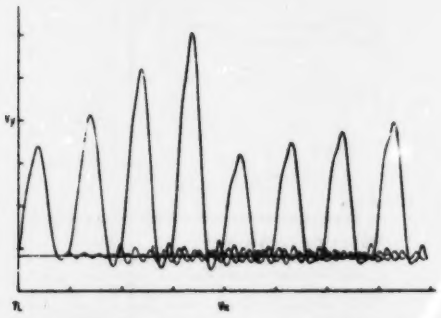


Fig. 11 - Pressure profiles obtained by dropping weight from 25 cm to 200 cm at 25 cm increments, with sandpaper between the intermediate weight and the anvil. The units are the same as in Fig. 10

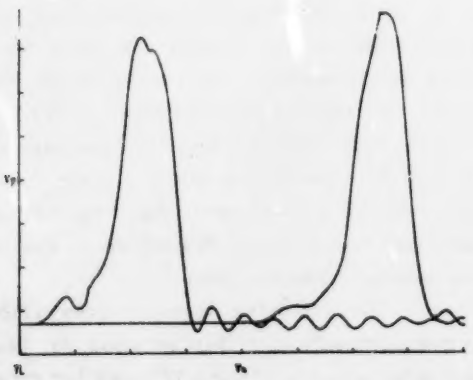


Fig 12. - Pressure profiles for Datasheet. The left shows no reaction while that on the right was considered a fire. The vertical scale is 0.25 v/div and the horizontal scale is 0.25 s/div

A fire usually causes a distinguishable, steeper sloped peak just to the left of the main peak. This feature is best seen in the pressure profiles for TNT in Fig. 13, where the explosion was much more violent. The same feature is visible to a lesser extent on the pressure profiles for a typical slurry explosive. These are shown in Fig. 14. Note the very irregular no-fire pulse in Fig. 13, for TNT, describing the compression on the granular material. Due to its ability to flow under impact, the main portion of the no-fire pulse for the slurry explosive is similar to that of Detasheet C.1.

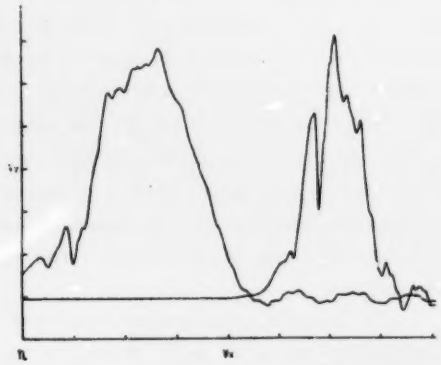


Fig. 13 - Pressure profiles for TNT. The left shows no reaction while that on the right was considered a fire. The vertical scale is 0.25 v/div. The horizontal scale is 0.0625 ms/div and 0.125 ms/div for the left and right curves respectively

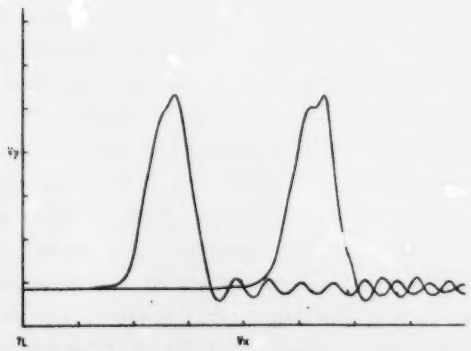


Fig. 14 - Pressure profiles for a slurry explosive. The left shows no reaction while that on the right was considered a fire. The vertical scale is 1.0 v/divd and the horizontal scale is 0.125 ms/div

In a future report an attempt will be made to integrate the pulses to the time of reaction and correlate this value to other sensitivity test results. Comparisons will also be made with results from other laboratories.

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